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Electrical Power Quality up gradation with Dynamic Voltage Restorer based on ESRFT Control Algorithm

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Abstract— *Voltage stability issue is a bigproblem ofelectrical power structure. The instability disturbed the functioning of sensitive devices.In power distribution networks only DVRis uniqueFACTS device that is used for the solution of above said problems. For DVR circuit ESRFT control algorithm is suggested to die out the harmonics as well as disturbances and provide a compensated voltage at the consumer end during abnormal condition in the electrical distribution structure. PI controller generateabase voltages feed to dynamic voltage restorerand maintained the voltage at the consumer end by means of voltage source inverter (VSI). The fast switching strength of IGBT facilitates the application of additional control technique to be responsible forvoltagecompensation against sag, swell and harmonics.This control scheme design is simple comparatively. MATLAB Simulation used to determine the results.*

Keywords: *Power system, power quality, FACT, DVR, IGBT, voltage sags/swells, PCC, VSI, ESRFT, MATLAB/SIMULINK.*

I. INTRODUCTION

Electrical energy distribution networkshould bemaintained continuity and reliability flow of energy ideally [1]. However, the distribution part of power system have large number of sensitive and nonlinear devices, which can disturbed the voltagestability. Due to the presence of sensitive or nonlinear devices, the quality of the power supplies disappeared and thus start growing many power quality issues. Besidessensitive devices capacitor switching, sudden apply or removal loads, symmetrical and unsymmetrical faults occurring in the power system could also affect power quality [2]. If fault occurs either in the transmission system or distribution system, voltage sag or swell introduced in the whole electrical distribution system or affect maximum portion of the power system. If heavy load sudden apply Voltagesag comes in to picturemay cause either failure of sensitive devices, instability or produce a large amount of unbalance current. The above results can be eliminates at the cost of complete damage of the device [1]. Voltage range for under voltage amplitude exist between 10% - 90% of rated voltage and range in between90% to 110% voltage is known as the nominal operation voltage. If fault occurs in the system and sustained forsometime then fault categorise as follows: time durations from 0.5 cycles to 30 cycles known as instantaneous fault, from 30 cycle to 3 sec known as momentary fault, from 3 second to 1 min known as temporary and if fault sustained more than 1 minute then fault known as either under voltage or over voltage depending upon the type of fault causes.

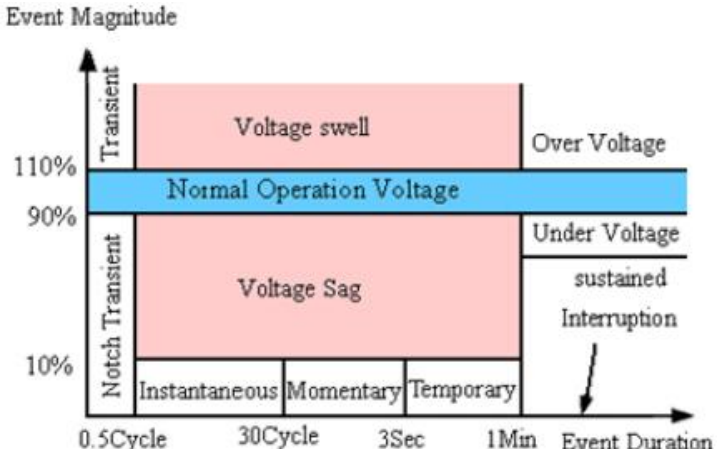

Figure 1.Voltage sag and swell representation.

Above 110% of rated voltage or a sudden raise in rated voltage or current known as voltage swell. The per unit magnitudes exist in the range between 1.1 and 1.8 pu[2].

FACTS devicesimplementation is the best way to advance the electrical power transmission capability and thus improve power system stability. The application ofelectronics controller in the electrical distribution network is termed as custom.So many FACTS app used in the electrical network to resolve the power quality related issues. All custom equipment's having some positive aspects and drawbacks. DVR having an ability to store more energythan SMES and UPS equipment. Furthermore, the DVRcost is less and having small size comparatively. On the basis of these points, it is conclude that the DVR can work effectively under abnormal conditionsto remove the voltage disturbances. DVR having some other features such as Power Factor and harmonics correction.

II. **Block Diagram representation of DVR**

DVR commonlynamed as Static Series Compensator used to ensure the reliability and continuity of rated load voltage and phase to compensate the power disturbancesoccurs in the distribution network at the fault point known as point of common coupling, PCC as shown in figure 3.

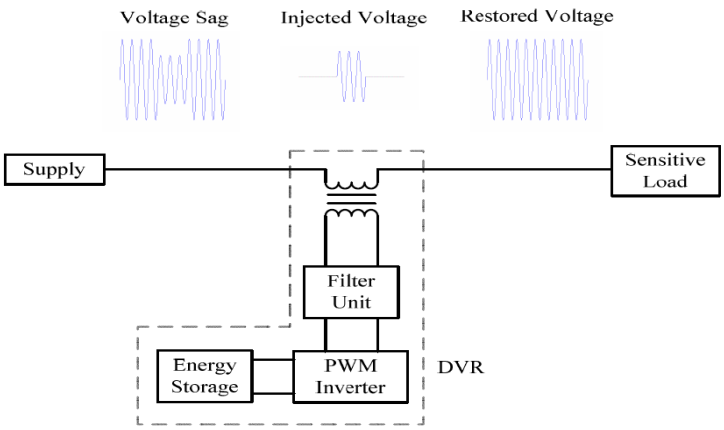

Figure 2. Block diagram representation of DVR.

The DVR contains following major parts

a. **Voltage Source Inverter**: As a step up transformers high current and lowvoltageratings of voltage source inverter introduce to raise the compensated voltage.
b. **Series Injection Transformers:** It is to design to provide maintained voltage to the sensitive load and connected in series with the power distribution section. The selection of KVA rating can be formulated as

$$\mathbf{kVA = V_c I_L / 1000}$$

c. **Passive Filters:** This type of filter is connected to the high voltage circuit so that harmonics will be die out from the system. Thus pure sinusoidal voltage feed to the non-linear loads.
d. **Energy storing Device:** If we have required active power compensation then Batteries, flywheels or SMEs play an important role for the proper functioning of sensitive loads. In case of large voltage sag problem active power compensation is necessary.
e. **DC Capacitor:** DVR should have a large DC capacitor so that it will be capable to provide stable DC output voltage and feed the inverter satisfactorily.
f. **By-Pass Switch:** When short circuit take place or fault occurs that's why the heavy current crosses a set limit flowing through the load side network. Here these switches come in to play and disconnected the DVR circuit from the system and provide another way for the flow of load current.
g. **Switching Frequency***:* The harmonics of highest order has taken in to consideration for the choice of switching frequency. It is also associated with speed of processor as the sampling frequency. The common choice of the switching frequency in between the 5 KHz and 20 KHz.

III. OPERATION OF DVR

During stable operation a dc capacitor will charge that is connected between an inverter and rectifier circuit. If short circuit occurs voltage sag comes in to existence and now this capacitor will starts discharging to provide stable voltage at

the load terminal. A difference will be observed between Nominal voltage and voltage sag after fault occurrence that is known as error signal. This voltage difference between rated voltage and actual voltage known as compensating voltage or injected voltage provided by the DVR circuit.

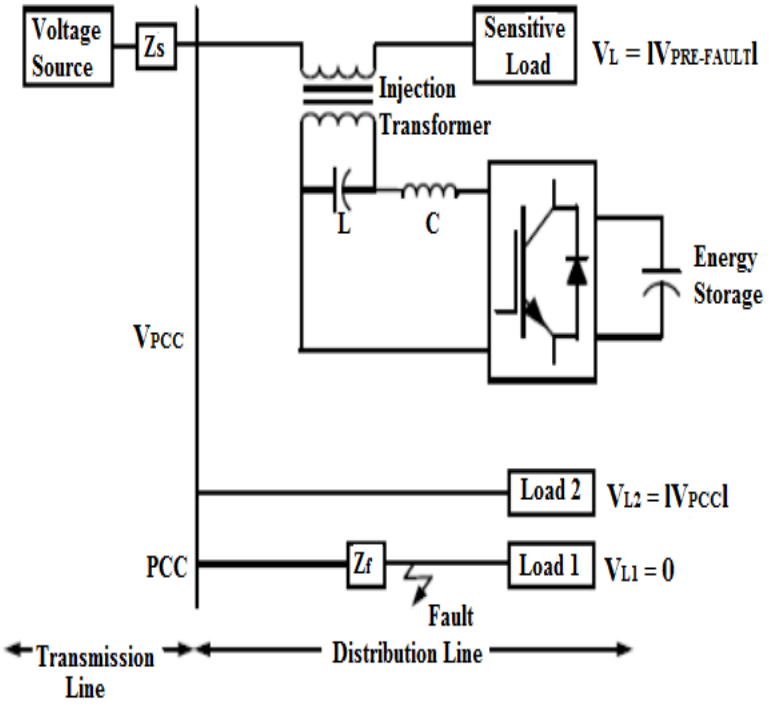

Figure 3. Typical arrangement of series connected arrangement.

To ensure the proper functioning of sensitive load voltage variation at the consumer end should be controlled. PWM technique is used for this special operation under abnormal condition. Reactive power should be provided through the DVR circuit to maintain the voltage at the load terminal.

IV. SCHEMATIC DIAGRAM OF DVR

The schematic diagram DVR based on ESRFT control algorithm is shown in figure 4. A balanced three phase supply voltages (Vsa,Vsb, Vsc) are feeding to the 3-phase sensitive loads through injection transformer. During abnormal condition power quality issues comes in to picture at the load terminal voltages. Now DVR circuit sense these disturbances, generates compensating voltages (V_Ca,V_{Cb},V_{Cc}), after injection by means of injection transformer provides smooth and stable load voltages (V_{ta},V_{tb},Vt_c) . A voltage source converter, DC capacitor and a ripple filter used to filter the switching ripple are the essential component of the DVR. A critical load, sensitive to power quality issues having lagging power factor used for this simulation work.

V. CONTROLLER BASED ON ESRFT CONTROL ALGORITHM

ESRFT based Controller(with fundamental extractor using SRFT) uses the concept of positive sequence extraction using SRFT theory. The component of direct axis is

$$V_{td} = V_{d\_const} + V_{d\_var} \quad (1)$$

Samples of line voltages help to determine direct axis component with PLL.

$$V_{td} = V_a \sin(\theta_1) + V_b \sin\left(\theta_1 - \frac{2\pi}{3}\right) + V_c \sin\left(\theta_1 + \frac{2\pi}{3}\right) \quad (2)$$

If $V_d$pass through low pass filter then peak value of positive sequence phase voltage $v_{d_const}$is obtained.This scheme will be implemented when distorted phase voltages having harmonics. Positivephase sequence components of phase voltages is then computed using $\sin\theta_1$ and $\cos\theta 1$ (output of PLL) as shown in figure 4.

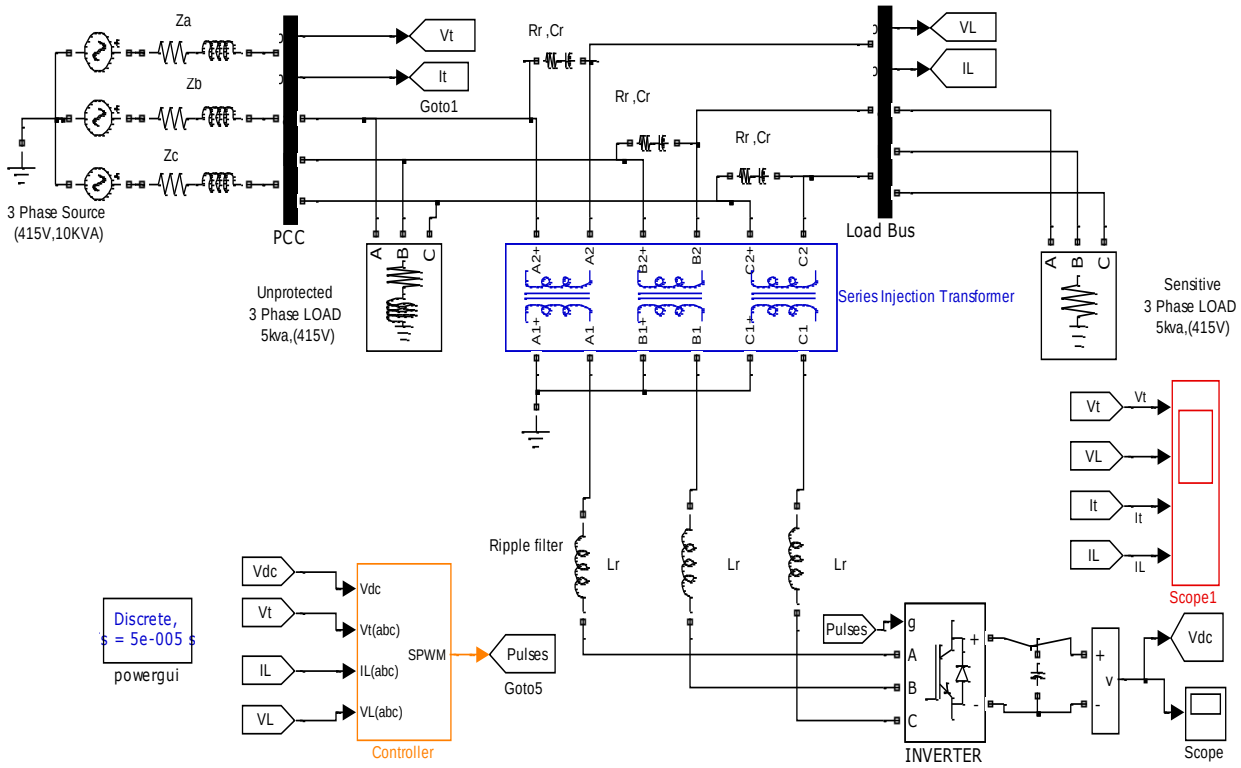

Figure 4. Schematic diagram of DVR based on ESRFT control algorithm.

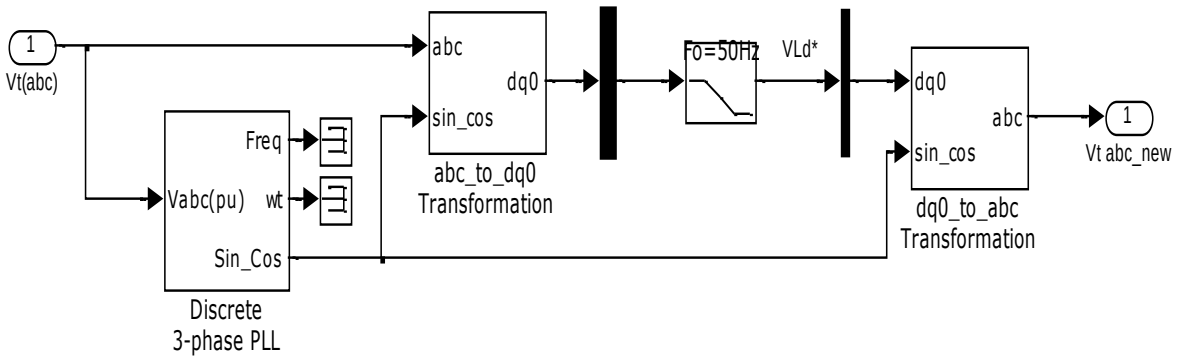

Figure 5.Fundamental extractor using SRFT.

$$\begin{bmatrix} V_{a1f} \\ V_{b1f} \\ V_{c1f} \end{bmatrix} = V_{d\_const} \begin{bmatrix} \sin\theta_1 \\ \sin\left(\theta_1 - \frac{2\pi}{3}\right) \\ \sin\left(\theta_1 + \frac{2\pi}{3}\right) \end{bmatrix} \quad (3)$$

Here extract positive sequence from the PCC voltage (V_t),which then transformed to direct axis and the quadrature axis component is derived from direct axis as per the relation (3) . Controller is shown in figure 5.After Controller actions d-q component transformed back in to a-b-c component.Now the resultant signal are considered as the reference signals andmatching with original output Voltage (V_L) at the load bus. Controller generate the error or difference signals and provide input to the PWM generator. A six pulsessequence obtained from PWM generator control the operation of converter based on IGBT.

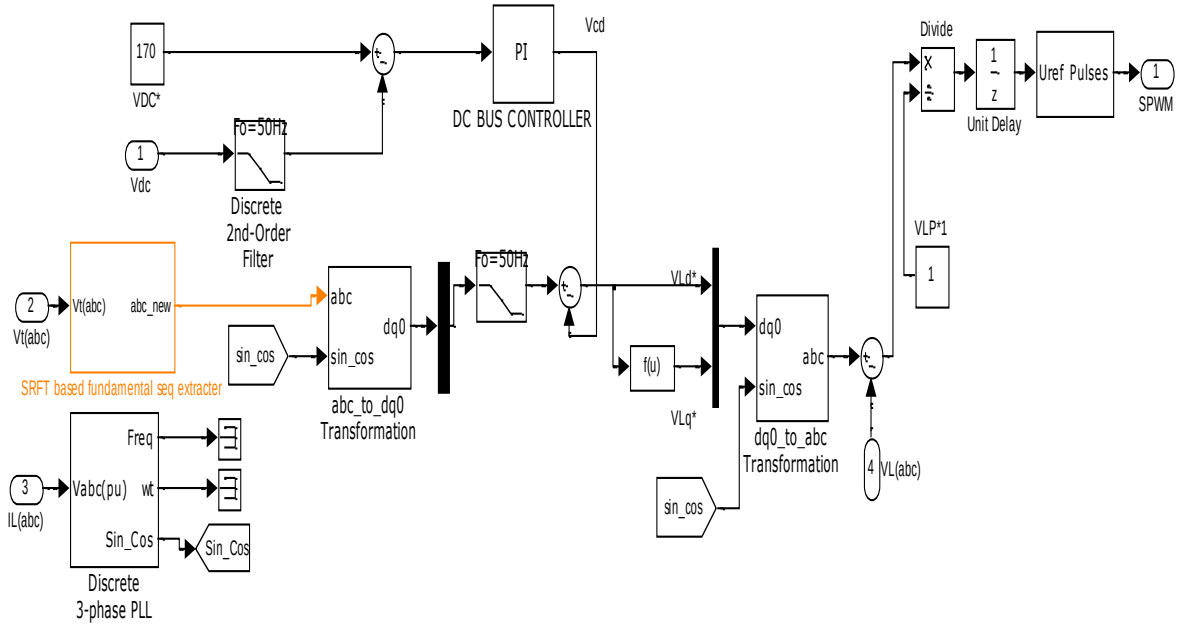

Figure 6. Controller based on ESRFT with SRFT based fundamental extractor.

VI. RESULTS AND DISCUSSION

CASE - I

For the simulation of MATLAB based DVR two types of faults are applied on a stable three phase (positive sequence)supply source so that unbalance effects recorded in all three phases.In first step fault introduce 3rd order harmonics having amplitude of 0.2, Phase Shift of - 250 and Zero Sequence. In second disturbance introduce 2nd order harmonics,Amplitude of -0.2p.u, Phase Shiftof 350 and Negative Sequence. For the clarification phase A waveforms are represent though waveform distortion occurs in all phase of three phase power system. Now DVR remove distortion from all three phases however phase A is observe. Therefore DVR restore, compensate and maintain the voltage in all three phases.

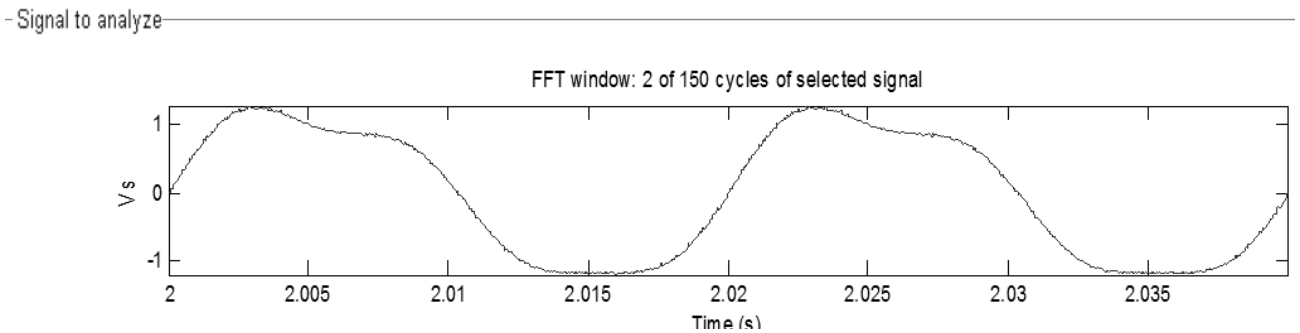

Figure 7. At the Point of Common Coupling voltage signal wave form of phase A(ESRFT, SRFT- FPS,Case-1).

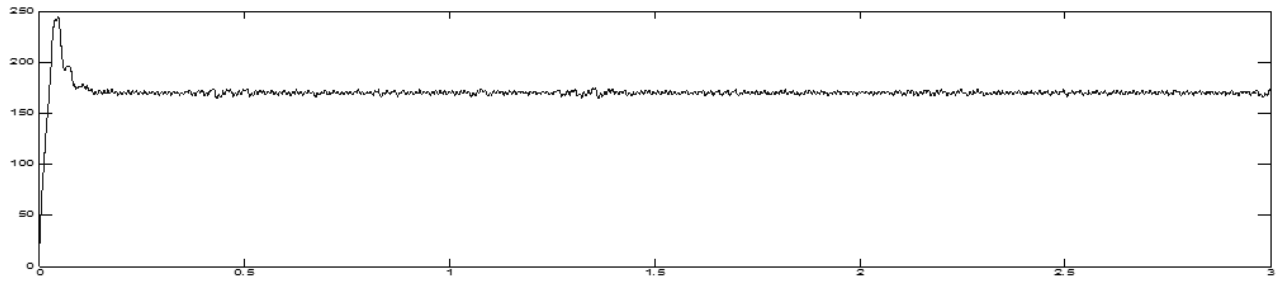

Figure 8. At the input end of inverter DC Link voltage wave form (ESRFT, SRFT-FPS,Case-1).

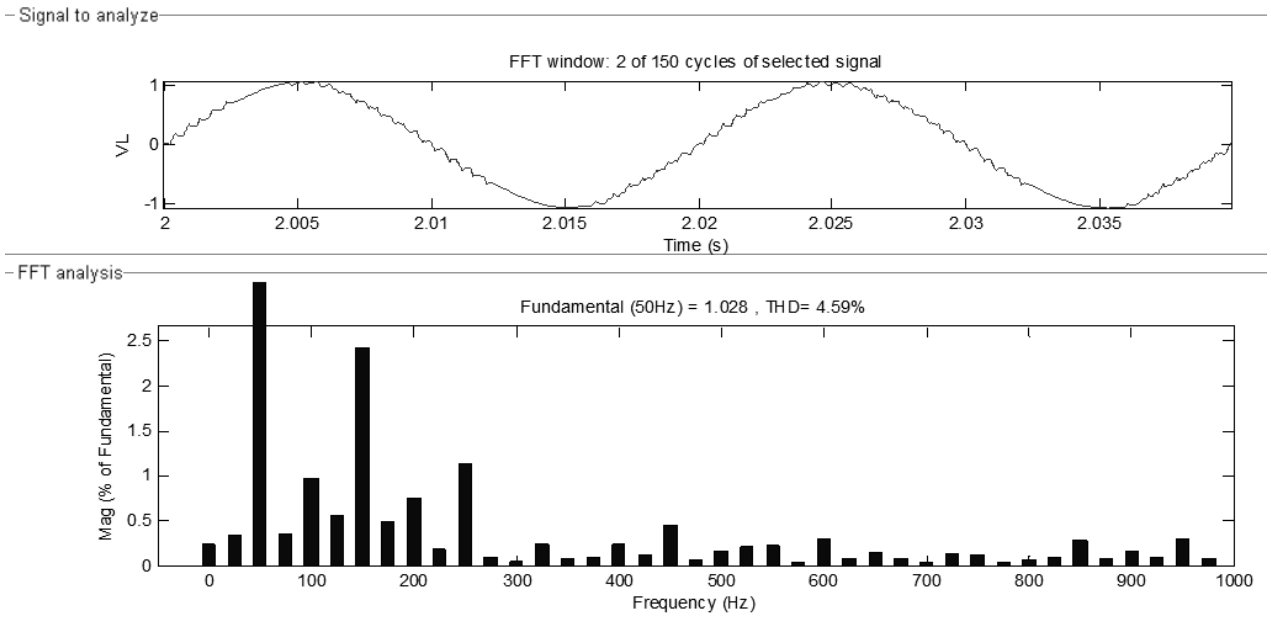

Figure 9.Phase - A wave form of load voltage and result of FFT analysis (Case-1).

The DVR controller performance is satisfying the demand and eliminate the Harmonics accurately. The scale of THD of input voltage noted as 18.9% andit is minimized up to 4.51% (average value) and maintained the magnitude upto 0.997p.u.(average value).

CASE - II

There are two types of faults are applying on the 3-phase balanced system. A Positive sequence source generatestransients in all three phase voltages. Type 1 fault is of 1stOrder, 0.3p.u,Amplitude, Phase Shift is of -250 and Zero Sequence.Type II fault is of 1stOrder, Amplitude is 0.2p.u, 350^{0}Phase Shift and Negative Sequence. FFT waveform analysis of phase A is only presented from the simplicity point of view.

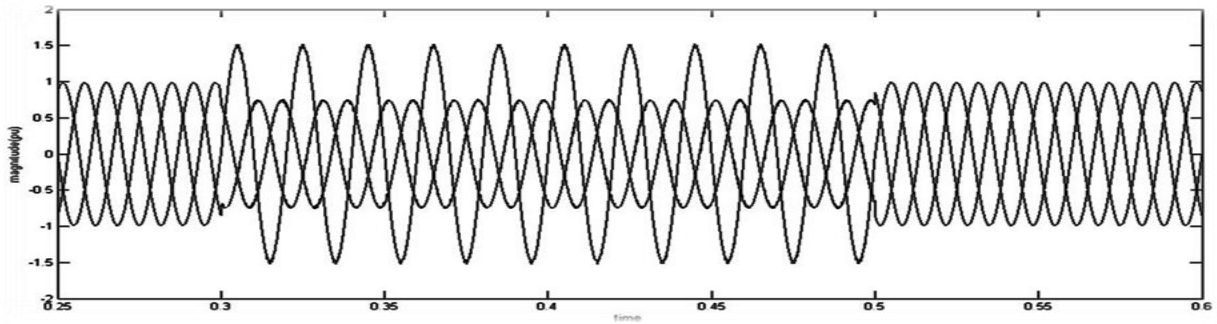

Figure 10.At the Point of Common Coupling Voltage Wave form(Case-2).

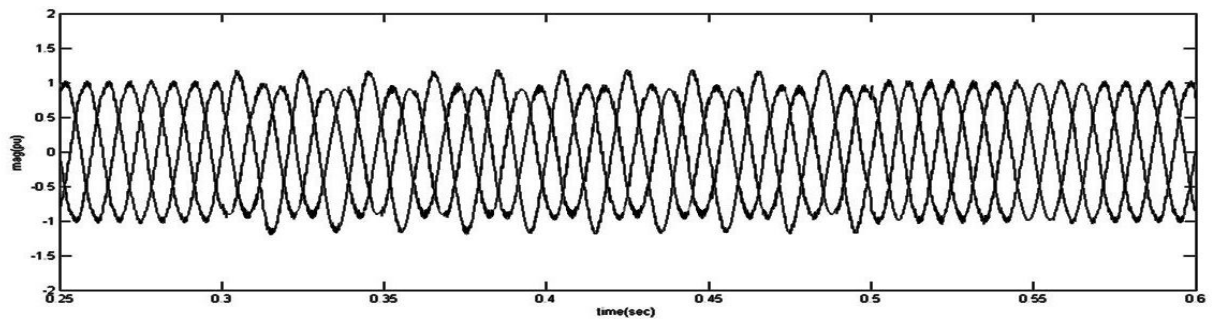

Figure 11.Wave form of load voltage based on ESRFT, SRFT- FPS. (Case-2).

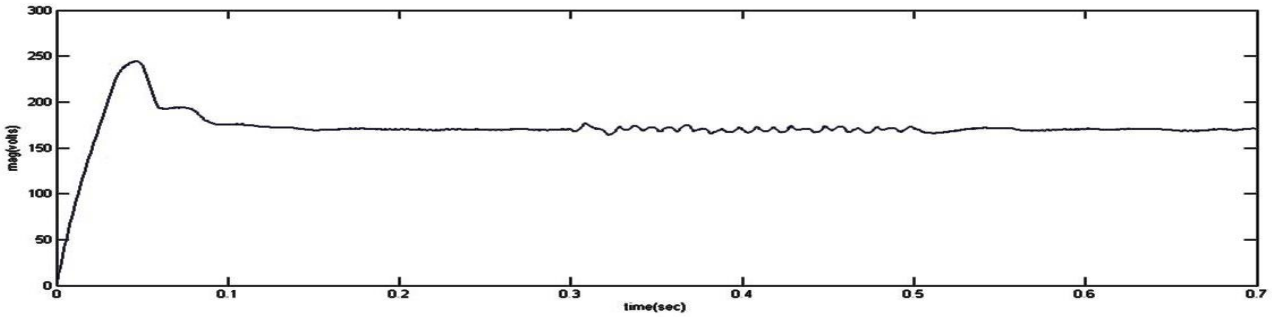

Figure 12. Wave form of DC Link Voltage at input of inverter based on ESRFT, SRFT- FPS (Case-2)

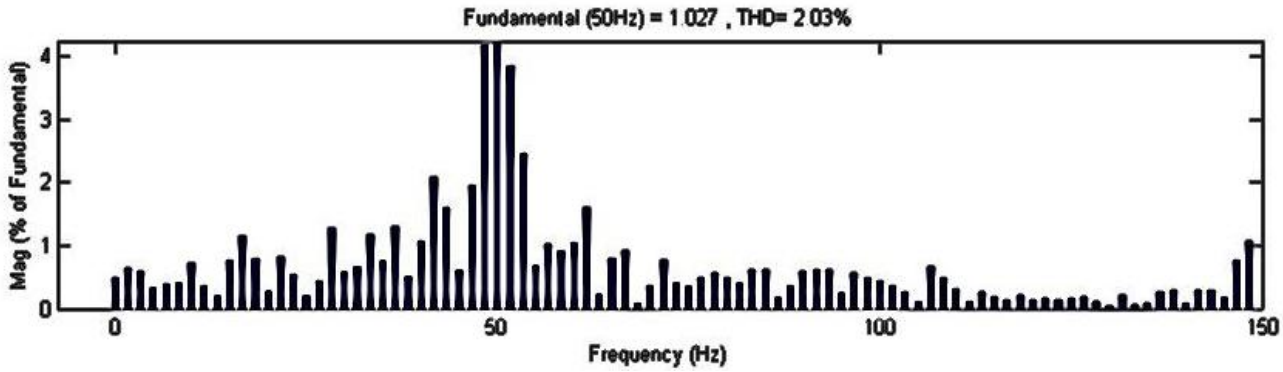

Figure 13. FFT waveform analysis of Phase A based on ESRFT, SRFT- FPS (Case-2) .

Table:1 Summary of Result (ESRFT, SRFT- FPS,Case-2)

Phase	Distorted Mag(p.u.)	compensated Mag(p.u.)	THD(%)
A	1.145	1.027	2.03
B	0.940	0.963	2.29
C	0.874	0.966	2.31

This controller works satisfactorily for Removal of unbalance.Using FFT analysis tool of MATLAB SIMULINK, it can be observed that DVR restores magnitude about 0.985(avg.) and THD to 2.21% (avg.) which are under specified standard limits.

VII. CONCLUSIONS

MATLAB based DVR model is simulatedand obtained satisfactorily results under abnormal conditions. DVR circuit restores the voltage magnitude about 0.985(avg.) and remove THD upto 2.21% (avg.) which are under specified standard limits. ThusDVR controller is able to sense various power quality difficulties and injection transformer gives the compensating voltage to remove the problem accurately as well as immediately. Hence Proposed DVR device successfully protects the most sensitivedevice against power quality problems.

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